METAL FLOW AND HEAT TRANSFER IN BILLET DC CASTING USING WAGSTAFF® OPTIFILL™ METAL DISTRIBUTION SYSTEMS

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Outline

• Introduction
• Model Description
• Result and Discussion
  – Metal fill and temperature contour
  – Metal fill start time and fill complete time
  – Metal temperature contour and flow during run cast
  – Metal temperature history and metal heat loss
• Summary
• Acknowledgements
Introduction

Goal: Optimize the design of a metal distribution system to improve metal fill uniformity, obtain consistent start-up process control and premium quality billet

• Decrease total metal fill time and Optimize fill uniformity - eliminate bleed-out, butt defects (hot/cold butt separations)
• Reduce heat loss - obtain less temperature gradient across casting positions
• Minimize turbulence and pre-solidification - Maintain good process and metallurgical quality
Original, RapidFill™ and OptiFill™

Original: simple and maximized pit utilization

RapidFill™: improve the uniformity of fill and reduce the total fill time and overall heat loss; but require superstructure with motorized start dam and might reduces the maximum number of billet positions

Investigation: Original and OptiFill™ systems:
- Metal fill uniformity and metal residence time
- Thermal, fluid flow fields and heat losses

OptiFill™: draws desirable features from both RapidFill™ and the Original systems, thereby maintaining simplicity while optimizing metal fill performance.
Model Development

• Billet Systems
  - 7" 96 strands, 6063
  - Original = 165" × 60.0"
  - OptiFill™ = 165" × 60.0"
  - Cavity cross section area

• The Model
  - Turbulent model
  - Thermal buoyancy convection
  - Solidification

• Meshing
  - Cell size = ~10 mm
  - Total cells = ~1.9 million

• Initial Condition (IC) and Boundary Condition (BC) Assumptions
  - $T_{\text{inlet metal}} = 700 \, ^\circ \text{C}$
  - Constant metal height = 110 mm
  - $T_{\text{refractory}} = 27 \, ^\circ \text{C}$
  - Run cast speed = 2.17mm/sec. (130.2mm/min)
Metal fill and temperature contours ~5.0 sec. after dams are tilted open
Metal fill and temperature contours ~15.0 sec. after the dams are tilted open.
Metal Fill and Temperature Contour

Original

OptiFill™

Metal fill and temperature contours at cast start
Metal Fill Uniformity

The metal fill start time, fill complete time and residence time for the two systems

Original

OptiFill™
Temperature Contour during Cast

Metal temperature contours at ~100 sec. of casting (Cast Length ≈ 199 mm)
Temperature Contour during Cast

Metal temperature contours at ~350sec casting (Cast Length ≈ 742 mm)
Temperature Contour and Flow

Metal temperature and flow at ~350 sec. casting
(~ 6.5 cm from trough bottom, cast length ≈ 742 mm)
Temperature History and Heat Loss

![Graph showing temperature history and heat loss over time for various conditions, including HotEnd_Original, ColdEnd_Original, HotEnd_OptiFill, and ColdEnd_OptiFill.](graph.png)
Summary

Heat transfer and fluid flow models for Original and Wagstaff® OptiFill™ metal distribution systems for billet casting have been developed to investigate metal flow and heat losses. Optifill™ has the following benefits:

• **Less fill start time difference in OptiFill™** (more metal to cold end early)
  OptiFill™ → ~4.6 sec, Original → ~17.4 sec

• **Less fill complete time difference in OptiFill™** (more metal to cold end)
  OptiFill™ → 11.2 sec, Original → 22.6 sec

• **Less total fill time in OptiFill™** (smaller runner trough + ingate + melt pool)
  OptiFill™ → ~21.1 sec, Original → ~26.3 sec

• **Less heat loss in OptiFill™** (faster metal flow in the runner trough)
  OptiFill™ → ΔT is ~15 °C less at start of cast and 3-5 °C less in run state
Rahab Original System to OptiFill™

Old System: 7” x 44 strands Original
Rehabbed System: 7” x 44 strands OptiFill™

Benefits:

- ~12 sec less total fill time (OptiFill™ = ~15.0 sec, Original = ~28.0 sec)
- ~10-15 °C less heat loss (OptiFill™ = ~10 °C, Original = ~20-25 °C)
- Consistent start-up process

Wagstaff® OptiFill™ metal distribution system is the preferable choice in production of premium quality billets
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